International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 4, Aug 2018, 167-178

OPTIMIZATION OF LIFTER OPERATIONS FOR INTER-LINE TRANSFERS IN SEMICONDUCTOR MANUFACTURING FACILITIES

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ABSTRACT

As semiconductor processes continue to be complex and the number of production steps is increased, a single floor line often comes to have not enough capacity to cover such production. Therefore, in recent years, multiple floors or multiple lines have been combined into a single Fab and this increases inter-floor (or inter-line) delivery. This increase in inter-floor delivery leads to a bottleneck, causing significant production loss. In this paper, we proposed operation policies of inter-floor delivery such as virtual ports, alternative storage, and shelf extraction procedure. In addition, the operational policy was examined through simulation experiments that can maximize the efficiency of inter-floor delivery. It has been found that having two or three virtual ports is the most efficient and activating the alternative storage option has the advantage of increasing the availability of the in-port. This paper focused on the actual problem that occurred in practice, and the results of this study can contribute to improving the efficiency of lifter operations in material handling of semiconductor lines.

***KEYWORDS:** Inter-Line Transfer, Material Handling, Semiconductor, Optimization, Simulation*

Received: May 10, 2018**; Accepted:** May 31, 2018**; Published:** Jun 30, 2018**; Paper Id.:** IJMPERDAUG201819

Original Article

INTRODUCTION

Semiconductors are indispensable in modern industry, and their demand is increasing. The operation of semiconductor production systems involves many challenging issues. With the development of the 300 mm Fab, the material handling in the semiconductor process is almost completely automated, and the efficiency of its delivery has been greatly improved. However, recent semiconductor Fabs are experiencing bottlenecks in automated material handling systems that have not been seen in the past. The bottlenecks occur in inter-floor (inter-line) delivery rather than in in-floor delivery. In this paper, we propose an operation policy of inter-floor delivery in automated material handling systems of semiconductor lines. In addition, the operational policy will be examined through simulation experiments that can maximize the efficiency of inter-floor delivery.

Na et al. (2016) outlined the delivery of semiconductor layers. Of those parts, only the parts related to this research are briefly summarized. Before the introduction of the 300 mm Fab, people delivered a found (a front opening unified pod) with a wafer. However, with the introduction of the 300mm Fab, an overhead hoist transport (OHT) as shown in Figure 1(a) now delivers the finished foups from one facility to the next, and this is called the automated material handling system (AMHS).

When an operation is completed in the existing facility, a delivery request command is issued and a nearby idle OHT moves to this facility to pick up the finished found. Then, along with the rails on the ceiling of

the line, the foup is delivered to the next facility and released. OHT sare responsible for in-floor delivery, and lifters are responsible for inter-floor delivery. A lifter acts as a kind of elevator in that they transport foups or people between different floors. Figure 1(b) shows an example of a lifter. Since a lifter and a zip tower play a similar role in the field, we refer to both as a lifter in this article.

(a) Example of OHTs (http://www.muratec.net/cfa/products/)

(b) Example of a Lifter http://www.daifuku.com/us/solution/products/)

Figure 1: OHT and Lifter in a Semiconductor Facility

Now we explain why the number of inter-floor deliveries increases. During a ramp-up period of a line, the workload of the inter-layer transfer is usually highest. Also, if the product mix changes, production scheduling is often not stabilized because yields are low and production steps have not yet been established. Thus, it is not easy to predict the capacity, yield, or work in process (WIP) for production facilities. As a result, there is often a temporary excess or shortage of production capacity, and to cover this, a production lot is taken from another line, and inter-floor or inter-line delivery increases.

Another reason for the increase in inter-floor delivery is that semiconductor processes continue to be complex and the number of steps required to produce a single product is increasing. In addition, lines built in the past have insufficient capacity to produce new products. Therefore, in recent years, multiple floors or multiple lines have been combined into a single Fab and this increases inter-floor delivery. This increase in inter-floor delivery leads to a bottleneck, causing a huge disruption to the production scheduling of the entire line for 10–20 minutes or occasionally even 1 hour or more, resulting in a huge loss in production. Therefore, it is the most important issue in semiconductor manufacturing to solve the delay in inter-floor delivery that is a serious bottleneck of the AMHS. In this study, we examine various operating policies of lifters that are responsible for delivery between different floors and propose effective policies for lifters by means of simulation tests.

This study is concerned with the improvement of efficiency in the semiconductor system. Agrawal and Heragu (2006) reviewed various issues related to semiconductor production. Mönch et al. (2011) classified various scheduling problems caused by the semiconductor production process. Most of the studies on AMHS in semiconductor manufacturing are related to OHT operation, which is responsible for in-floor delivery. Kim et al. (2007, 2009), Bozer and Yen (1996), and Le-Anh and de Koster (2005) have studied OHT assignments and Bartlett et al. studied routing algorithms after job assignment. Kim and Park (2009) studied how the delivery efficiency varies depending on the idle OHT policy. Our research is different from the previous studies because it deals with the inter-floor delivery rather than with the in-floor logistics. Another topic related to this study is the storage system called a stocker. Cardarelli and Pelagagge (1995) presented simulation modeling and test results of the stock storage system for Fabs material handling. In the previous research, the main role of a stocker is to store the four. However, our research focuses on the role of the inter-floor delivery

for a lifter or zip.

Mackulak and Savory (2001)comparing the productivity differences using discrete event simulations for two intra-bay layouts within a segregated Fab. Jimenez et al. (2002) focused on inter-bay delivery in segregated Fabs, and presented simulation results. In these two papers, the segregated Fabs have the structure of old lines, where the Fabs is divided into several regions. Each region is connected through a stocker. Nowadays, segregated Fabs are no longer used and all areas in the line have been replaced by one Fabs structure where OHTs can be reached at one time. Therefore, previous papers on segregated Fabs are also different from our study.

The study of Na et al. (2016) is the most relevant to our research. They introduced a lifter for inter-floor delivery in the AMHS of semiconductor lines and proposed methods to optimize the lifter assignment policy. Four methods were presented for how to assign a real-time delivery command to each lifter when there are several lifters on a line. In addition, they conducted a comparison experiment for each method. The first method is a round-robin method used in practice. The new methods are the minimum load assignment, the minimum arrival prediction time assignment, and the assignment by linear programming. Our study differs from Na et al.'s (2016) in that they studied improving the efficiency of inter-floor delivery by changing the lifter assignment method. However, our study will examine the other operation policies for a lifter, such as the virtual port, the alternative storage for enhancing the availability of the in-port, and the lot extraction order in the lifter shelf. Although the lifter assignment policy of Na et al. (2016)play an important role in making inter-floor delivery more efficient, lifter-related operational policies to be covered in this study will also have a major influence on inter-layer delivery efficiency.

In Section 2, we discuss lifter systems responsible for inter-floor delivery and their operational policies. In Section 3, we present the results of simulation experiments on operating policies, and in Section 4, we will present conclusions and suggestions.

METHODS

In this section, we explain the process of a lifter handling inter-floor deliveries and operational policies associated with it. There can be from 2 to 8 lifters that are responsible for the inter-floor delivery, depending on the size of the line and the number of the inter-floor deliveries. One lifter delivers one found at a time. The OHT picks up the groups when work is complete in a facility. If the destination is on a different floor, the OHT will transport the foup to the in-port, a kind of entrance in the lifter. In addition, a robot, called a rack-master, in the lifter will move the foup downstairs (or upstairs). Then, when the four comes out of the out-port of the opposite floor, the OHT picks it up and delivers it to the destination facility to complete the inter-floor delivery. Figure 2 shows the structure of the lifter system and inter-floor delivery. As mentioned earlier, lifters are often the bottleneck in an AMHS. To see how to prevent bottlenecks in inter-floor delivery, we will look at three operational policies related to lifters: policies for virtual ports, alternative storage, and shelf extractions.

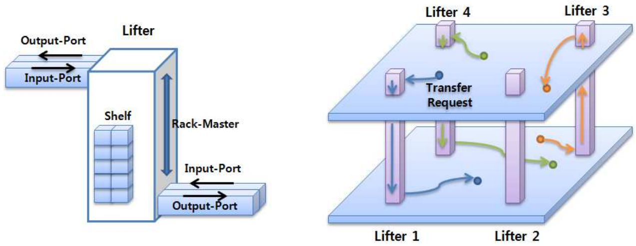

Figure 2: Structure of a Lifter and Inter-Line Transfer Request (Na et al. (2016))

Operating Policies for Virtual Ports

In general, a rack-master can move only one foup at a time. To maximize the utilization of a rack-master, several in-ports are placed in a queue to reduce the downtime of the rack-master. When a foup goes to the in-port of the lifter from the starting facility, the system does not reserve a specific in-port. The system determines which lifter to go through for the inter-floor delivery, and then takes considers the allowance of the in-port.

At the time when the inter-floor transfer request was issued, suppose that it was sent to the lifter of which an in-port was available. While this foup is moving from the starting equipment to the lifter another foups may arrive and occupy the in-port. Hence, there will be no available in-port for the foup. In this case, because the OHT rail is moving in one direction and there is no nearby parking area, the OHT will turn around once and attempt to access the in-port again. This phenomenon is called an “retrial” in practice. Up to three retrials will be attempted, and if there is still no available in-port, the foup will go to another lifter, which is called “alternative delivery.” On the other hand, even if there is no available in-port for a specific lifter when a transfer request is issued, the in-port may be available at the time the foup arrives at it. This is because the rack-master has 20–30 seconds to deliver one foup to another floor, whereas in-floor delivery takes 1–4 minutes.

As mentioned above, the efficiency of the inter-floor delivery depends on the availability of the in-port. The concept of a virtual port has been introduced to increase the utilization rate of the rack-master by making maximum use of the in-port. Compared with the delivery time from the facility to the lifter's in-port, the rack-master takes much less time to move a four to another floor. The virtual port is responsible for increasing the size of the queue by recognizing that there are more than the actual number of in-ports. Suppose that a lifter has two in-ports and three virtual ports. Though two groups occupy all the queues in the actual in-ports, virtual ports are available and more groups can head for this lifter. Therefore, the lifetime of the lifter can be increased by minimizing the time during which the in-ports are empty.

The sum of the actual ports and virtual ports is defined as the maximum reservation count. That is, the sum of the actual number of in-ports and the number of virtual ports is the maximum number of transfer requests that can be directed to a specific lifter at a time. The sum of the number of groups currently present in the in-port and the number of groups s that have not yet arrived at the in-port but are heading in that direction is called the current reservation count. If the maximum number of reservations of a specific lifter is six and the current number of reservations is five, then it can accommodate one more transfer request. If the current number of reservations is equal to the maximum number of reservations, a transfer request can no longer be sent to this lifter. Then, after the rack-master finishes the delivery of a foup, the current number of reservations is reduced, and the lifter can receive a transfer request again.

We can increase the maximum number of reservations by increasing the number of virtual ports. Then, the number of transfer requests to the lifter increases and the utilization rate of the lifter can be maximized. However, the number of actual in-ports is limited. If too many transfer requests are directed to a specific lifter, when the foups arrives at the lifter, all the in-ports are occupied and many retrials may occur. Therefore, it is not always good to increase the number of virtual ports too much. It is important to find the appropriate number of virtual ports because retrials can cause serious congestion near a particular lifter in material handling.

Alternative Storage Policy

If the in-port queue is always busy and there are many retrials, we can consider a policy of alternative storage. When this option is enabled, one foup is moved to the shelf in the lifter if more than one foup is present in the in-port. In other words, it is an operating policy that attempts to empty the in-port by temporarily moving the found in the in-port to the shelf to increase the availability of the in-port.

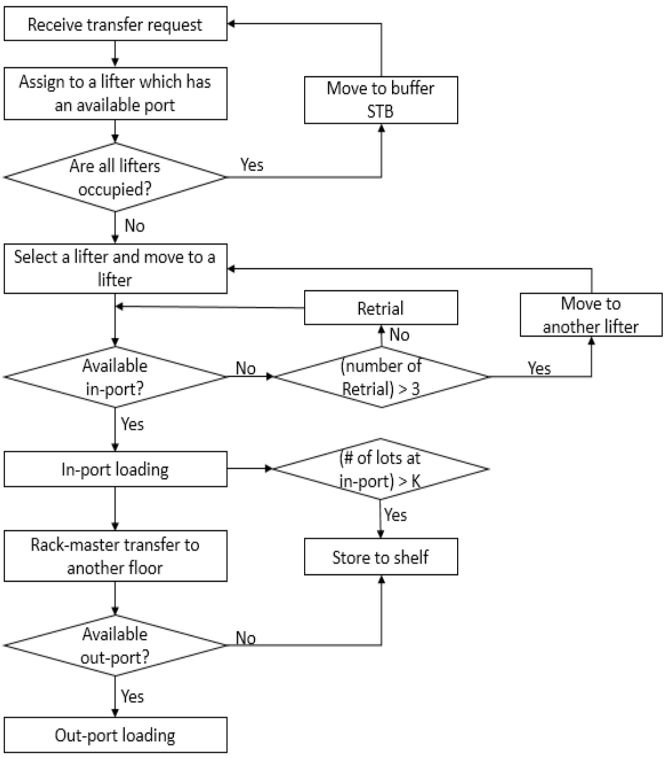

Figure 3: Flowchart for Lifter Operations

Operating Policies for Shelf Extraction Procedure

The shelf in the lifter serves as temporary storage. As described above, because of "alternative storage," there may be foups stored temporarily on the shelf in the lifter. In addition, when a foup attempts to go to the out-port of the opposite floor, the foup may temporarily be stored on the shelf if there is no available out-port. Therefore, there are three places that the rack-master needs to pick up: a foup on the shelf, a foup at the in-port of the current floor, or a foup at the in-port of the opposite floor. If the rack-master has finished the previous job and becomes available, the rack-master should decide which found to pick up.

Figure 3 shows the flowchart of lifter operations and foup movement according to various policies described above. In the next section, we present a simulation-based solution for which the policy can maximize inter-floor delivery

efficiency.

RESULTS

In the simulation experiment of this study, we tried to maximize the simulation consistency by using the actual parameters and field data without filtering as much as possible. To verify the effectiveness of various policies for lifters, we used version 12.3 of AutoMod, which is specialized software for material handling simulation. After completing the simulation modeling, we first verified whether the modeling reflected the lifter behavior in practice. If the simulations were carried out using the same rules as in the real world, the difference between the actual line and simulation modeling was within 5%. Hence, it can be said that the simulation model would reflect lifter behaviors of the actual line. Details of the simulation model are as follows.

- The number of in-ports and out-ports used in the current line is shown in Table 1.
- Experiments were conducted on a line with six lifters connecting floor A and floor B.
- Inter-floor delivery requests in the simulation are obtained from the inter-floor delivery history of the real line for 24 hours.
- The simulation for in-floor delivery is not within the scope of this study. Hence, we use the average delivery time from a facility to a lifter or from a lifter to a facility after extracting data for 30 days'history.
- The time that the rack-master picks up a foup from the in-port and moves it to the opposite floor is almost constant, so it is set to 24 seconds.
- The time for OHT loading or unloading is set as 10 seconds.
- If the rack-master has moved a foup to the opposite floor, but there is no available out-port, it waits for5 seconds. However, if there is still no available port, it is stored on the shelf in the lifter.
- If there is no available in-port and the retrial occurs, the return time to this in-port is set to 30 seconds.
- A retrial is performed up to three times for one lifter. If there is still no available in-port, alternative delivery will be performed to move to another lifter.

The utilization ratio of the rack-master, the average delivery time, the number of retrials, and the waiting time on the port will be used as simulation indicators.

Table 1: Number of Input, Virtual, and Output Ports

	Port	Port Type	Lifter Index					
			1	2	3	4	5	6
Line A → Line B	Input	Physical	3	5	3	3	3	3
		Virtual	5	3	5	5	5	2
		Max Sched. Count	8	8	8	8	8	5
	Output	Physical	3	5	3	3	3	3
Line B → Line A	Input	Physical	3	5	3	3	3	3
		Virtual	3	1	3	3	3	3
		Max Sched. Count	6	6	6	6	6	6
	Output	Physical	3	5	3	3	3	3

Simulation Results for the Number of Virtual Ports

Table 2 shows the results when adding virtual ports to the existing ports. As the number of virtual ports increases, the travel time is reduced from floor A to floor B. If there is no virtual port, it takes an average of 496 seconds from A to B, but if there is more than one virtual port, it will be less than 422 seconds. If more virtual ports may be added, the average delivery time will decrease, but not significantly. When moving from floor B to floor A, the average delivery time is decreased by increasing the number of virtual ports, but the decrease is not as great from floor A to floor B. As the number of virtual ports is increased, the average number of groups waiting on the in-port increases, but the waiting time for the in-port does not increase.

Table 2: Results on the Number of Virtual Ports

		Port+0	Port+1	Port+2	Port+3	Port+4
Delivery Time (seconds)	Line A → Line B	496.0	421.9	419.2	416.7	418.2
	Line B → Line A	437.5	432.3	431.9	429.7	431.0
Std. Dev. Of Delivery Time (seconds)	Line A → Line B	165.3	73.5	74.3	70.2	70.2
	Line B → Line A	73.5	70.7	71.5	70.4	69.8
Number of Retrials	Line A → Line B	0	0	15	24	32
	Line B → Line A	0	0	7	3	3
Number of Alternative Deliveries	Line A → Line B	0	8	0	1	1
	Line B → Line A	0	2	0	0	0
Rack-master Utilization (%)	Minimum	75.3	77.5	77.7	79.2	79.1
	Average	79.4	79.5	79.4	79.4	79.4
	Maximum	94.3	85.3	81.7	79.9	80.0
Number of TRs through STBs	Line A → Line B	3,562	601	15	0	0
	Line B → Line A	1,284	120	6	0	0
Number of Lots at Input Port	Line A → Line B	0.41	0.48	0.54	0.56	0.58
	Line B → Line A	0.44	0.50	0.52	0.51	0.53
Number of Lots at Output Port	Line A → Line B	0.42	0.42	0.44	0.43	0.44
	Line B → Line A	0.50	0.52	0.56	0.58	0.60
Waiting Time at Input Port (seconds)	Line A → Line B	43.2	44.0	44.6	42.2	42.4
	Line B → Line A	39.6	38.9	40.2	38.4	38.5
Waiting Time at Output Port (seconds)	Line A → Line B	33.3	33.3	33.4	33.3	33.6
	Line B → Line A	43.5	42.9	43.3	42.9	43.5

The average utilization ratio of the rack-master is similar even if the number of virtual ports is increased. However,

as the number of virtual ports is increased, the minimum utilization ratio among the lifters increases, and the maximum utilization ratio among the lifters decreases. In other words, the variation in utilization ratio for the six lifters is reduced. This is because more virtual ports increase the number of queues waiting on the in-port, thereby increasing the queue of rack-master jobs and reducing the idle time of the rack-master.

It is notable that if the number of virtual ports is set to zero, then more than half of the total deliveries go through the STB (Side-Track-Buffer). In this case, if a foup is assigned to a specific port, it occupies the in-port to prevent another foup from arriving. Therefore, the other foups will not be able to arrive until the reserved foup arrives at the in-port. If all lifters have no available port, the foup cannot go to any lifter and has to head to the buffer STB. Therefore, setting at least one virtual port is a better way to increase the utilization ratio of the rack-master. Also, as the number of virtual ports is increased, the number of retrials increases while the number of deliveries via STB decreases. However, considering that the total number of transfer requests is about 10,000, the number of retrials is less than 40, so the ratio is insignificant. Therefore, even if the virtual ports is increased, it can be seen that the number of retrials does not increase enough to cause congestion in the in-floor delivery.

Simulation Results for Alternative Storage

Table 3 shows the simulation results for the alternative storage. Activating the alternative storage option temporarily reduces the latency in the in-port because it temporarily moves a foup in the in-port to the shelf of the lifter. The average number of four in the in-port will thus be reduced. The biggest problem, however, is that the number of foups going to the shelves increases by more than 3,000. Therefore, the average moving time also increases greatly from about 420 seconds to about 490 seconds. Although the utilization ratio of the rack-master increases from 80% to 87%, the increased utilization is for temporarily moving groups to the shelf rather than for actual inter-floor delivery, so there is an increase in delivery time. The number of retrials is reduced by reducing the number of found in the in-port.

Table 3: Results on Alternative Storage Options

		Alt Storage Off	**Alt Storage On**
Delivery Time (seconds)	A → B	419.0	488.7
	B → A	430.6	489.3
Std. Dev. Of Delivery Time (seconds)	A → B	70.9	295.8
	B → A	71.0	276.9
Number of Lots through Shelves	A → B	1	1833
	B → A	0	1492
Number of Retrials	A → B	38	18
	B → A	24	9
Number of Alternative Deliveries	A → B	2	0
	B → A	0	0
Rack-master Utilization (%)	Minimum	79.1	86.9
	Average	79.8	87.3
	Maximum	80.5	87.9
Number of TRs through STBs	A → B	0	0
	B → A	0	0
Number of Lots at Input Port	A → B	0.57	0.46
	B → A	0.51	0.45
Number of Lots	A → B	0.43	0.44

at Output Port	B → A	0.56	0.57
Waiting Time at Input Port (seconds)	A → B	43.3	34.9
	B → A	39.3	34.3
Waiting Time at Output Port (seconds)	A → B	33.2	33.7
	B → A	42.9	43.6

Table 4: Results on Shelf Retrieval Options

		Shelf 1	Shelf 2	Shelf 3
Delivery Time (seconds)	A → B	488.7	495.9	458.9
	B → A	489.3	502.6	453.8
Std. Dev. of Delivery Time (seconds)	A → B	295.8	270.6	149.7
	B → A	276.9	264.7	110.8
Shelf Waiting Time (seconds)		287.0	323.6	183.2
Number of Retrials	A → B	18	22	10
	B → A	9	10	13
Number of Alternative Deliveries	A → B	0	0	0
	B → A	0	0	0
Rack-master utilization (%)	Minimum	86.9	86.5	80.4
	Average	87.3	87.5	81.2
	Maximum	87.9	88.5	81.9
Number of TRs through STBs	A → B	0	0	0
	B → A	0	0	0
Number of Lots at Input Port	A → B	0.46	0.46	0.42
	B → A	0.45	0.45	0.41
Number of Lots at Output Port	A → B	0.44	0.43	0.44
	B → A	0.57	0.57	0.56
Waiting Time at Input Port (seconds)	A → B	34.9	35.0	32.3
	B → A	34.3	34.7	31.6
Waiting Time at Output Port (seconds)	A → B	33.7	33.3	33.6
	B → A	43.6	43.5	42.7

Therefore, activating the alternative storage option has both positive and negative aspects. In terms of the utilization ratio of the rack-master and reducing delivery time, activating the alternative storage option is a bad option. If the utilization ratio of the rack-master or delivery time of the lifter is not significant, and retrials are frequent and congestion on the floor is too serious, activating the alternative storage may be a good option.

Simulation Results for Shelf Extraction Policy

In this simulation experiment, a rack-master decides which foup to pick up after it finishes the previous task and becomes idle. When it places a specific foup on the out-port, the previous task is over. If there is a foup in the in-port on the current floor, it is of course, the highest priority to pick up the foup and move it to the opposite floor. However, if there is no foup in the current floor, the rack-master must decide what to do. This is a current rule used in practice. If a foup exists in the in-port on the opposite floor, the rack-master moves to the opposite floor. If there is no foup on the opposite floor, the foup on the shelf is randomly selected and delivered to the destination. For convenience, it is called Shelf 1.

Two new policies are proposed. The first is that if there is no foup on the current floor, check the in-port of the opposite floor. If there is no foup on the opposite floor, the rack-master picks up the foup that is has been on the shelf for the longest time and moves it to the destination. This policy is known as first-in-first-out (FIFO). We call this policy Shelf 2.

The final policy is as follows. If there is no foup on the current floor, the rack-master picks up the foup from the shelf and goes to the opposite floor. Then, as soon as this delivery is completed, the rack-master picks up a foup on the arriving floor. In other words, the third policy is that the rack-master moves to the opposite floor after picking up a foup from the shelf. For convenience, we call this policy Shelf 3.

Table 4 shows the simulation results for the three shelf operating policies. The first policy (Shelf 1) was not much different from the second policy (Shelf 2). The third policy (Shelf 3) reduced the average delivery time and the deviation greatly. In addition, the waiting time in the shelf decreased from 300 to 183 seconds; hence, if there is no groups on the current floor, it is better to go through the shelf in the lifter rather than go directly to the opposite floor. The Shelf 3 policy is intuitively efficient.

CONCLUSIONS

In this study, the operating policy of the lifter system responsible for the inter-floor delivery of semiconductor lines has been discussed. First, in terms of virtual port configuration, it has been found that having two or three virtual ports is the most efficient in terms of reducing the inter-floor delivery time, the number of retrials, and the rack-master utilization ratio. Activating the alternative storage option has the advantage of increasing the availability of the in-port, but will increase the inter-floor delivery time. Therefore, the alternative storage option is not recommended unless there is a special situation of the line. Finally, in the method of extracting a foup from the shelf in a lifter, having the rack master pick up a foup from a shelf in a lifter while moving to the opposite floor and then delivering it to the opposite floor is efficient.

This study is difficult to generalize as a mathematical model. However, we focused on the problem that occurred in practice on real semiconductor lines, and we utilized the actual data as much as possible. Therefore, the results of this study can contribute to improving the efficiency of lifter operations in material handling of semiconductor lines.

ACKNOWLEDGEMENTS

Jinpyo Lee's work was supported by 2016 Hongik University Research Fund. Seungbeom Kim's work was supported by 2018 Hongik University Research Fund.

REFERENCES

1. *Agrawal, G. K., & Heragu, S. S. (2006). A survey of automated material handling systems in 300-mm SemiconductorFabs. IEEE transactions on semiconductor manufacturing, 19(1), 112-120.*

2. *Bartlett, K., Lee, J., Ahmed, S., Nemhauser, G., Sokol, J., & Na, B. (2014). Congestion-aware dynamic routing in automated material handling systems. Computers & Industrial Engineering, 70, 176-182.*

3. *Bozer, Y. A., & Yen, C. K. (1996). Intelligent dispatching rules for trip-based material handling systems. Journal of Manufacturing Systems, 15(4), 226-239.*

4. *Cardarelli, E., & Pelagagge, P. M. (1995). Simulation tool for design and management optimization of automated interbay material handling and storage systems for large wafer fab. IEEE Transactions on Semiconductor Manufacturing, 8(1), 44-49.*

5. *Jimenez, J., Kim, B., Fowler, J., Mackulak, G., Choung, Y. I., & Kim, D. J. (2002). Material handling: operational modeling and simulation of an inter-bay AMHS in semiconductor wafer fabrication. In Proceedings of the 34th conference on Winter simulation: exploring new frontiers (pp. 1377-1382). Winter Simulation Conference.*

6. *Kim, B. I., Oh, S., Shin, J., Jung, M., Chae, J., & Lee, S. (2007). Effectiveness of vehicle reassignment in a large-scale overhead hoist transport system. International journal of production research, 45(4), 789-802.*

7. *Kim, B. I., & Park, J. (2009). Idle vehicle circulation policies in a semiconductor FAB. Journal of Intelligent Manufacturing, 20(6), 709.*

8. *Kim, B. I., Shin, J., Jeong, S., & Koo, J. (2009). Effective overhead hoist transport dispatching based on the Hungarian algorithm for a large semiconductor FAB. International Journal of Production Research, 47(10), 2823-2834.*

9. *Le-Anh*, T., & De Koster, M. B. M. (2005). On-line dispatching rules for vehicle-based internal transport systems. International Journal of Production Research, 43(8), 1711-1728.*

10. *Mackulak, G. T., & Savory, P. (2001). A simulation-based experiment for comparing AMHS performance in a semiconductor fabrication facility. IEEE transactions on semiconductor manufacturing, 14(3), 273-280.*

11. *Mönch, L., Fowler, J. W., Dauzère-Pérès, S., Mason, S. J., & Rose, O. (2011). A survey of problems, solution techniques, and future challenges in scheduling semiconductor manufacturing operations. Journal of scheduling, 14(6), 583-599.*

12. *Na, B., Woo, J. E., & Lee, J. (2016). Lifter assignment problem for inter-line transfers in semiconductor manufacturing facilities. The International Journal of Advanced Manufacturing Technology, 86(5-8), 1615-1626.*